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REPORT NO. 316

PLASTICS AND RUBBERS SECTION

COMPOSITE MATERIALS FOR SABOT APPLICATIONS

PROJECT NUMBER 1L162105 A329 AH84

FISCAL YEAR 1981

BY

F. A. MCLAUGHLIN, PRINCIPAL INVESTIGATOR
C. CARMAN
K. HUGHES
W. RIDER

FEBRUARY 1982

ORGANIC MATERIALS BRANCH

MATERIALS & MANUFACTURING TECHNOLOGY DIVISION
FC&SCWSL

DOVER, NEW JERSEY

44744

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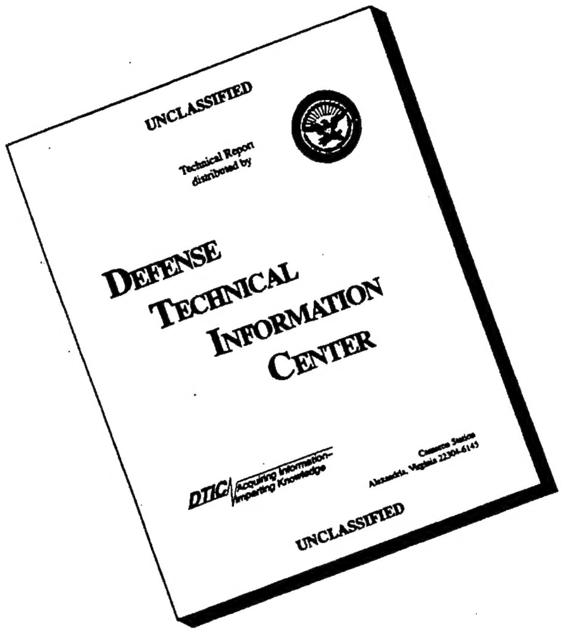

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APPROVED BY: __________________________
MERRILL EIG
C, Plastics & Rubbers Sec, OMB, M&MTD, FC&SCWSL

Organic Materials Branch
Materials and Manufacturing Technology Division
Army Armament Research and Development Command
Dover, New Jersey 07801

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BACKGROUND

Previous efforts have shown the need for physical property data of plastics at various strain rates. A test program was developed that included testing for shear, compression and tension at three strain rates. Included in this program was limited testing at low and elevated temperatures. Details of the program were reported in the FY80 status report for AH84.

During FY81, the program was taken from the conceptual stage to an ongoing active effort. Material selections were made, specimen designs were selected, specimens were injection molded, test fixtures were designed and fabricated, correlations between specimen designs were established, correlations between different strain measurement methods were determined and tensile testing at several strain rates and temperatures were conducted. Each of these efforts is reported in detail in this report.

DISCUSSION

Material Selection

It was desired that the first group of materials to be tested in this program include those materials presently used and being considered for use in military applications. The materials should be of the type commonly referred to as "engineering plastics" and should be readily available. They should also have been on the market long enough to have developed a history. The three materials selected for testing meet the above requirements. They are polycarbonate, acetal copolymer and nylon 6 (Table 1). All three materials are commercially available and were supplied in the unfilled natural state. In addition to being tested in its natural state, the nylon 6 was also obtained

with a 30% glass fiberfill. This was done in order to develop some initial data on the effect of filler on plastics subjected to high loading rates.

Specimen Selection

The test program as outlined in Ref 1 contained both machined test specimens and molded high hat specimens. However, following the decision to do all testing in-house, a review of specimen configuration was conducted. This review determined that injection molded specimens would be better suited for the in-house test equipment, easier to fabricate and less likely to have any influence on material performance. It was also desired that the specimen configurations be such as to correlate with previous high rate work (Ref 2), be of a standard accepted type and be easy to fabricate. Table 2 lists the specimens that were selected. The selected specimens included one design for compression, one for shear and two for tension testing. The most common specimen for tensile testing is the tension bar in accordance with ASTM D638 type II. This specimen was adequate for the low (10^{-3} in/in/sec) and the medium (10^{1} in/in/sec) strain rate tests but was notadequate for the high (10^{3} in/in/sec) strain rate test due to machine limitations. Therefore, it was decided to use the tension bar for the low and medium strain rate testing and a tension impact specimen per ASTM D1822 for the high strain rate testing.

Test Equipment

All testing for this program was performed by the Physical Mechanics Section of M&MTD, FC&SCWSL. The equipment used is listed in Table 3. As can be seen, the equipment is state-of-the-art equipment and is used industry wide in testing of a large variety of materials. The equipment should have no effect on the physical property data that is developed during this program.

Specimen Molding

All the specimens were molded in the Organic Materials Branch, M&MTD, FC&SCWSL molding facility. The tension, compression and shear specimens were molded in a family molded mounted in a 2000 ton, 12 oz, Cincinnati Milacron screw injection molding machine. The tension impact bar was molded in a 25 ton 1 oz. Newberry Industries screw injection molding machine. All resin supplier molding recommendations were strictly followed. All specimens were molded from a single batch of material. Once the molding conditions were established for a material, all the specimens required for the program were molded without any interruption of the cycle. If, during the molding, there was a machine malfunction or delay that caused a cycle change, all specimens molded prior to the cycle change were discarded and molding was started over.

Post molding handling of the specimens were in accordance with the resin supplier's recommendations. In the case of the nylon material, two different sets of post molding moisture conditioning were followed as directed by the supplier. All specimens were placed in "zip-lock" polyethylene bags and stored in the testing laboratory until required for testing.

Shear Testing

A small hole is drilled in the center of the specimen and the specimen is mounted into the specimen holder (Fig. 1). The specimen and holder are then placed between the loading platens. The lower platen is recessed to receive the specimens. As the compressive load is applied, the specimen is held flat and a circular hole to the diameter of the specimen holder is sheared out of the center of the specimen.

Tension Bar vs. Tension-Impact Bar

As discussed earlier, there was a need to use two different tension specimen configurations due to limitations imposed by the test equipment. The tension bar was to be used for low and medium strain rates and the tension impact for the high strain rate. It was therefore necessary to determine if the two specimens produced different results when tested at a common rate. This was needed to insure that value differences noted at the various strain rates would be due to the effect of strain rate and not to the specimen configuration. Figures 2-5 show the stress-strain curves for several materials using tension bars and tension impact bars. The curves show little significant difference in values obtained from the two different specimen configurations.

Strain Measurements

There are two methods commonly used to measure strain during a tensile test. One is to use an extensometer mounted on the specimen and record the output from it. The other is record the position of the cross-head on the test equipment as the test is conducted. At the low and medium strain rates, the extensometer with the tension bar can be easily used. However, the extensometer could not be used with the tension impact bar because of the lack of sufficient gage length to fasten the extensometer. Therefore, testing was conducted where strain measurements were recorded by both methods in order to determine the influence that the measurement method had on the results. Figure 2-5 shows the results of these tests for the various materials and shows no sufficient differences between the strain measurement methods.

Tension Testing

Tensile testing using both tension bar specimens and tension impact specimens were conducted as previously discussed. Each of the four materials were tested in a tensile mode at the low and the medium strain rate. Figures 6-17 are the stress vs. strain curves developed from these tests. Table 4 is a comparision of the tensile properties of each material as a function of the strain rate. Further data reduction including data interpretation, will be accomplished in FY82.

Temperature

Limited tensile testing at -45°F and 145°F was conducted in order to get a "first look" at the effect of temperature when combined with the effect of strain rate on the physical properties. Figure 18 shows the stress-strain curve for polycarbonate tested at a strain rate of 10^{-3} in/in/sec at -45°F, +70°F and +145°F. This phase of the program is in its early development with no definitive results as yet.

CONCLUSIONS

- Three unfilled and one filled plastics were selected for evaluation.
- Tension, compression and shear specimen configurations were selected.
- A shear fixture was designed and fabricated.
- Correlation was established between tension bar and tension impact bar specimens.
- Correlation was established between two strain measurement methods.
- Tensile testing was completed on each of the materials at 10^{-3} in/in/sec and 10^{1} in/in/sec.
- Tensile testing of polycarbonate at $-45^{o}F$, $+70^{o}F$ and $+145^{o}F$ was completed.

REFERENCES

1. F. A. McLaughlin, Status Report Project 16162105 AH84, FY1980.

2. U.S. Lindholm and L.M. Yeakley, Static and Dynamic Confined Compression Testing of Plastic Materials, Southwest Research Institute, Sept 1975.

TABLE 1

SELECTED MATERIALS

ACETAL Done

POLYCARBONATE

NYLON 6

NYLON 6 WITH GLASS FIBER (30%)

TABLE 2

TEST SPECIMENS

TEST	SPECIMEN
TENSION	TENSILE BAR (ASTM D638, TYPE II)
	TENSION-IMPACT BAR (ASTM D1822)
SHEAR	2-IN DISK (ASTM D732)
COMPRESSION	1/4 x 1/2 x 1/2 (ASTM D695)

TABLE 3

TEST EQUIPMENT

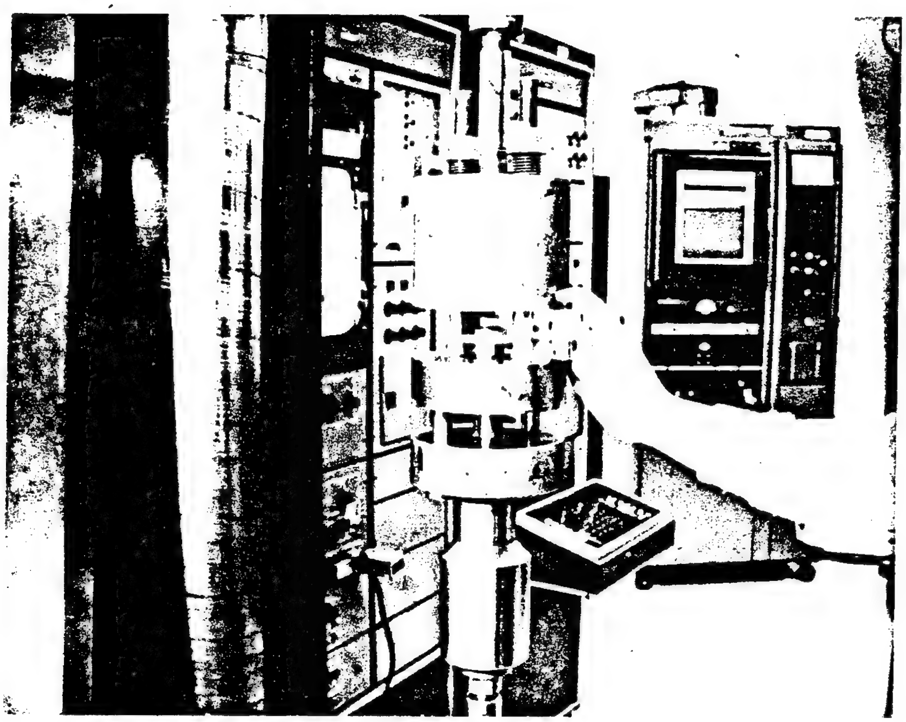
STRAIN RATE	EQUIPMENT
10^{-3} IN/IN/SEC	MECHANICAL (INSTRON)
10^{1} IN/IN/SEC	SERVO-CONTROLLED HYDRAULIC (MTS)
10^{3} IN/IN/SEC	SERVO-CONTROLLED HYDRAULIC (MTS) PLUS TRANSIENT RECORDER (TEKTRONIX)

TABLE 4

TENSILE YIELD (PSI) VS. STRAIN RATE

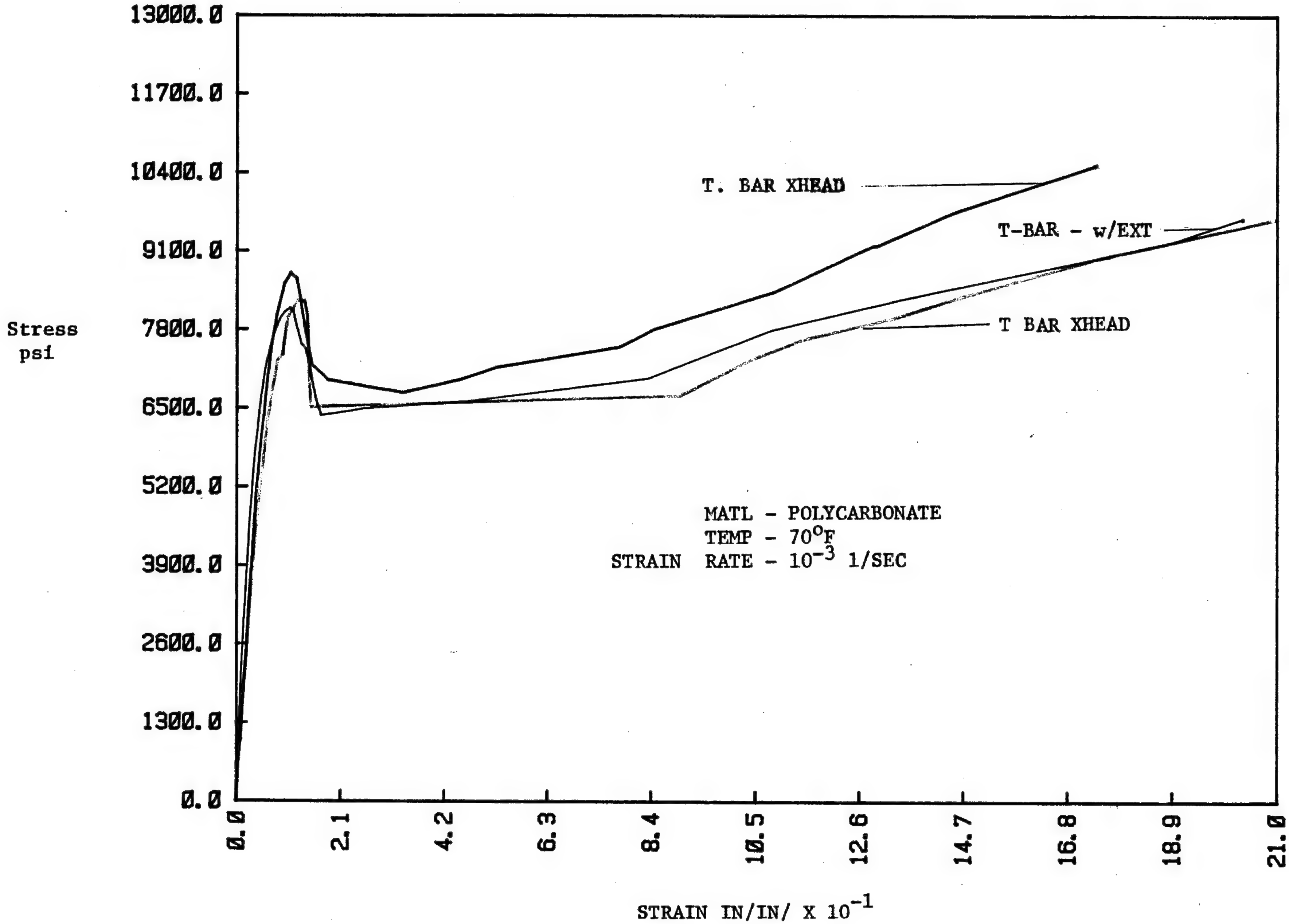
MATERIAL	STRAIN RATE		
	$1x10^{-3}$ in/in/sec	$1.6x10^{-3}$ in/in/sec*	1x10' in/in/sec
POLYCARBONATE	8,700	9,000	9,800
NYLON 6	6,000	6,400	9,600
NYLON 6 w/30% GF	14,000	23,500	25,500
ACETAL	8,000	8,800	10,120

*PUBLISHED DATA



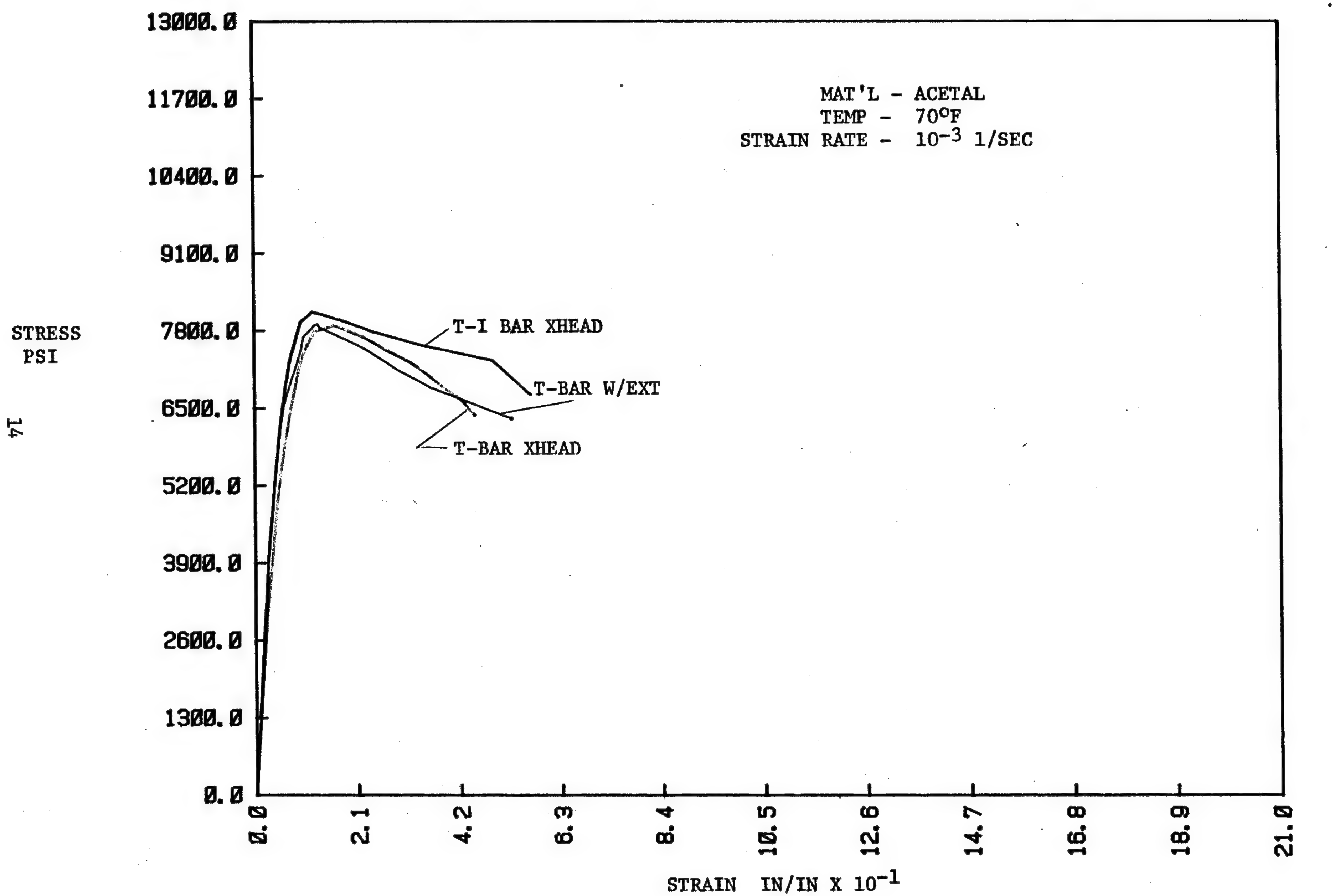
SHEAR
[redacted] FIXTURE

FIGURE 1



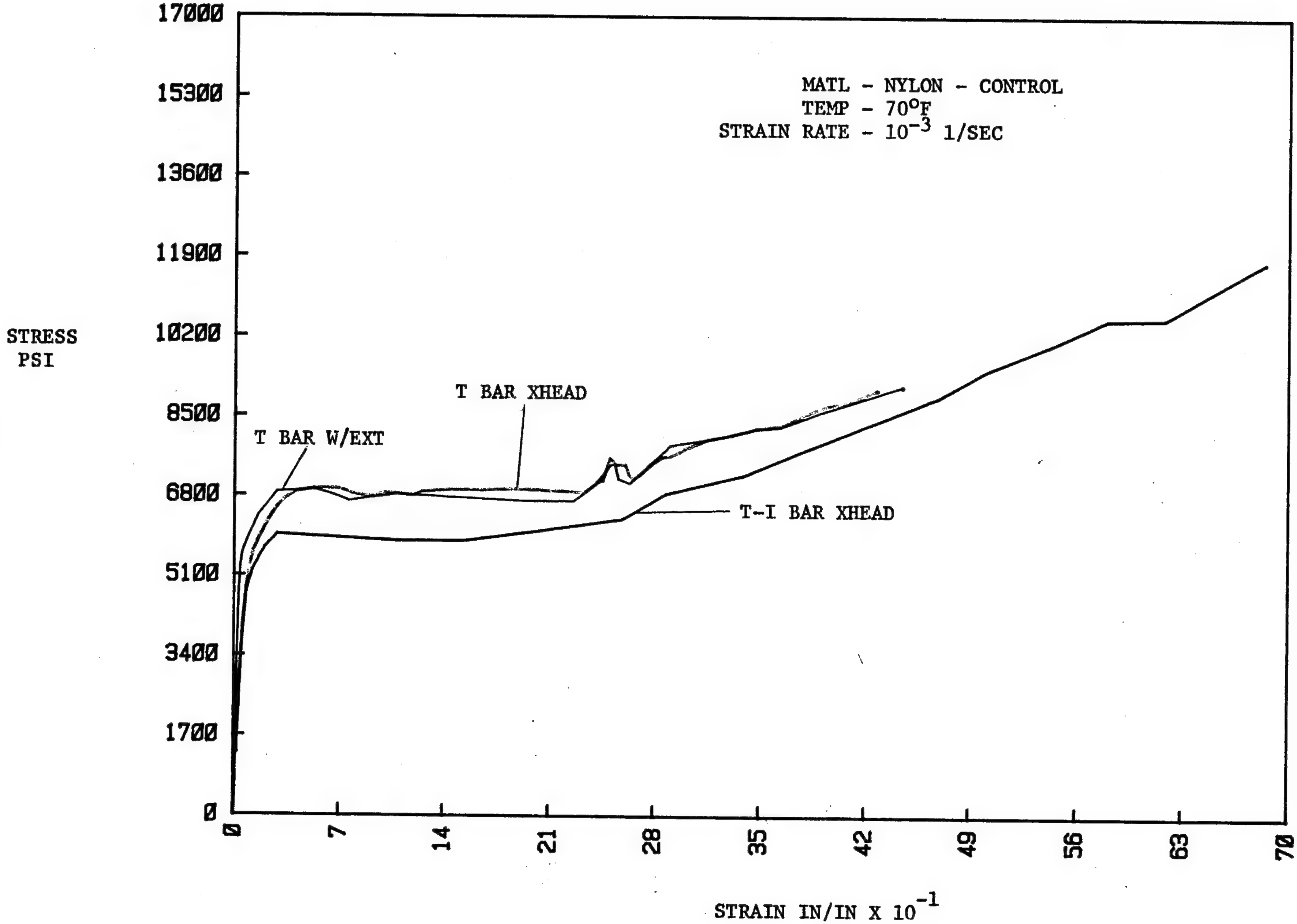
13000.0
11700.0
10400.0
9100.0
7800.0
6500.0
5200.0
3900.0
2600.0
1300.0
0.0
Stress
psi
T. BAR XHEAD
T-BAR - w/EXT
T BAR XHEAD
MATL - POLYCARBONATE
TEMP - 70°F
STRAIN RATE - 10^-3 1/SEC
0.0
2.1
4.2
6.3
8.4
10.5
12.6
14.7
16.8
18.9
21.0
STRAIN IN/IN/ X 10^-1

FIGURE 2



STRESS
PSI
13000.0
11700.0
10400.0
9100.0
7800.0
6500.0
5200.0
3900.0
2600.0
1300.0
0.0
MAT'L - ACETAL
TEMP - 70°F
STRAIN RATE - 10-3 1/SEC
T-I BAR XHEAD
T-BAR W/EXT
T-BAR XHEAD
0.0
2.1
4.2
6.3
8.4
10.5
12.6
14.7
16.8
18.9
21.0
STRAIN IN/IN X 10-1

FIGURE 3



MATL - NYLON - CONTROL
TEMP - 70°F
STRAIN RATE - 10^-3 1/SEC
T BAR XHEAD
T BAR W/EXT
T-I BAR XHEAD
STRESS PSI
17000
15300
13600
11900
10200
8500
6800
5100
3400
1700
0
0
7
14
21
28
35
42
49
56
63
70
STRAIN IN/IN X 10^-1

FIGURE 4

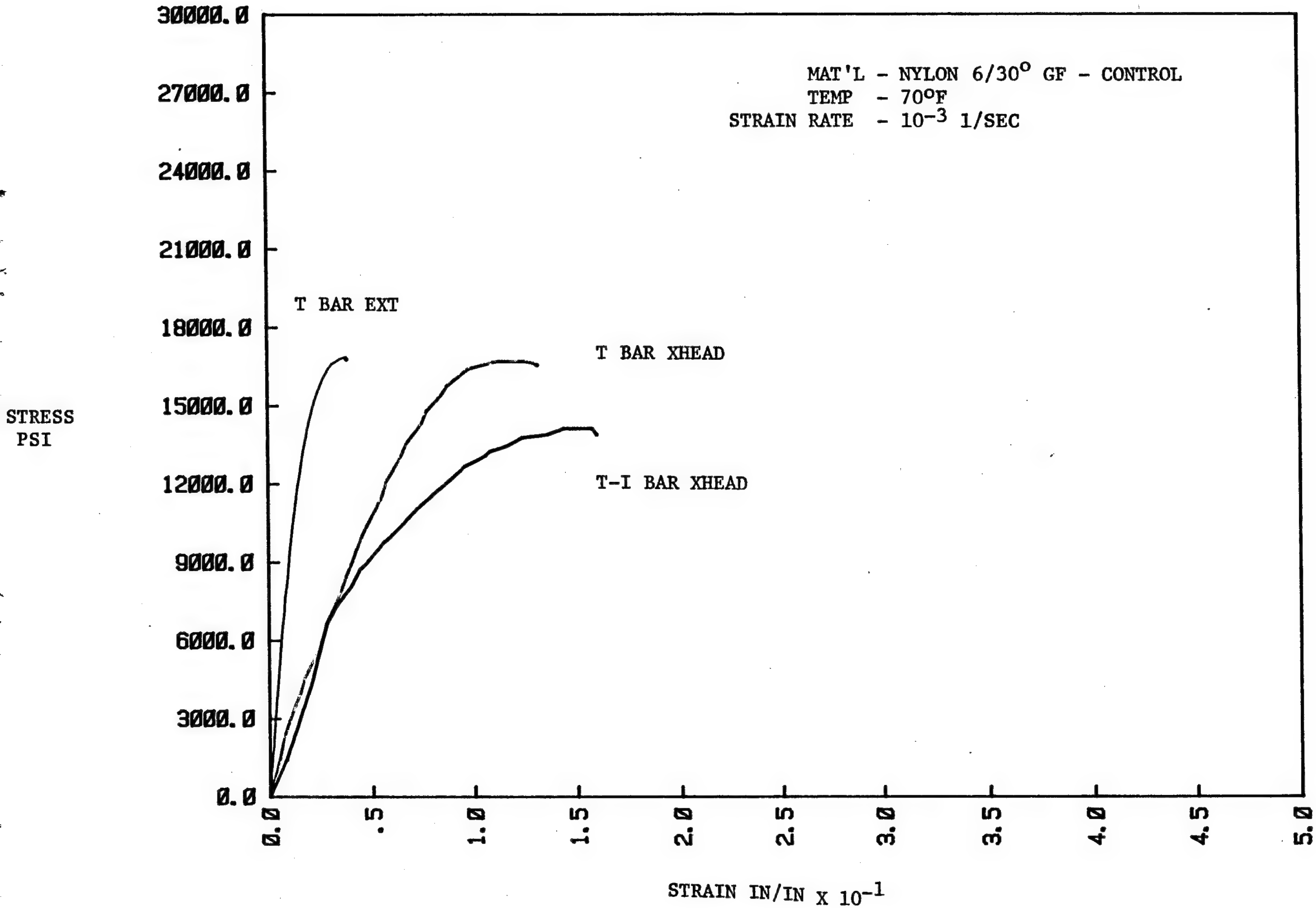

MAT'L - NYLON 6/30° GF - CONTROL
TEMP - 70°F
STRAIN RATE - 10-3 1/SEC
T BAR EXT
T BAR XHEAD
T-I BAR XHEAD
STRESS PSI
30000.0
27000.0
24000.0
21000.0
18000.0
15000.0
12000.0
9000.0
6000.0
3000.0
0.0
0.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
STRAIN IN/IN X 10-1

FIGURE 5

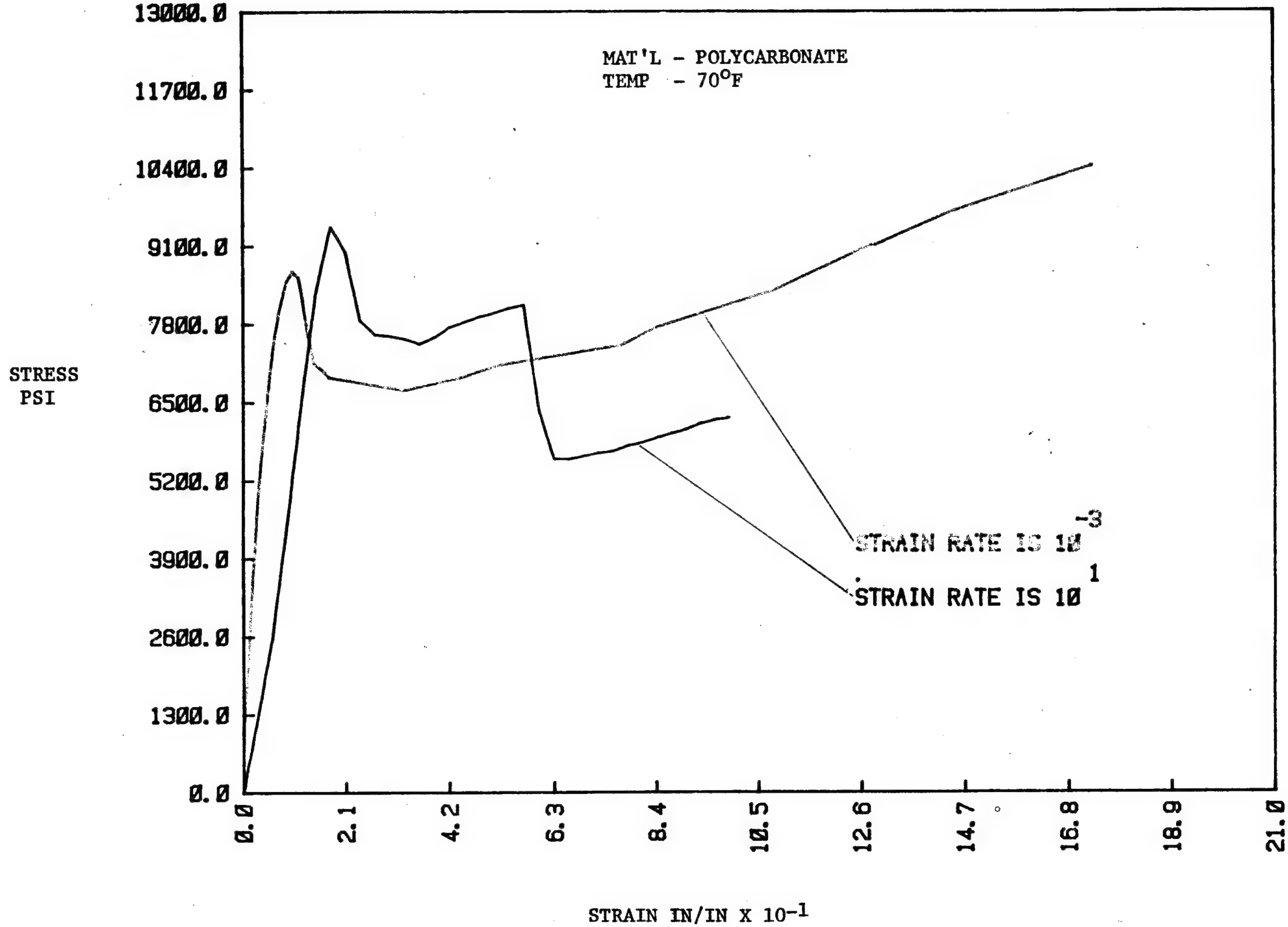

MAT'L - POLYCARBONATE
TEMP - 70°F
STRESS PSI
13000.0
11700.0
10400.0
9100.0
7800.0
6500.0
5200.0
3900.0
2600.0
1300.0
0.0
0.0
2.1
4.2
6.3
8.4
10.5
12.6
14.7
16.8
18.9
21.0
STRAIN RATE IS 10^-3
STRAIN RATE IS 10^1
STRAIN IN/IN X 10^-1

FIGURE 6

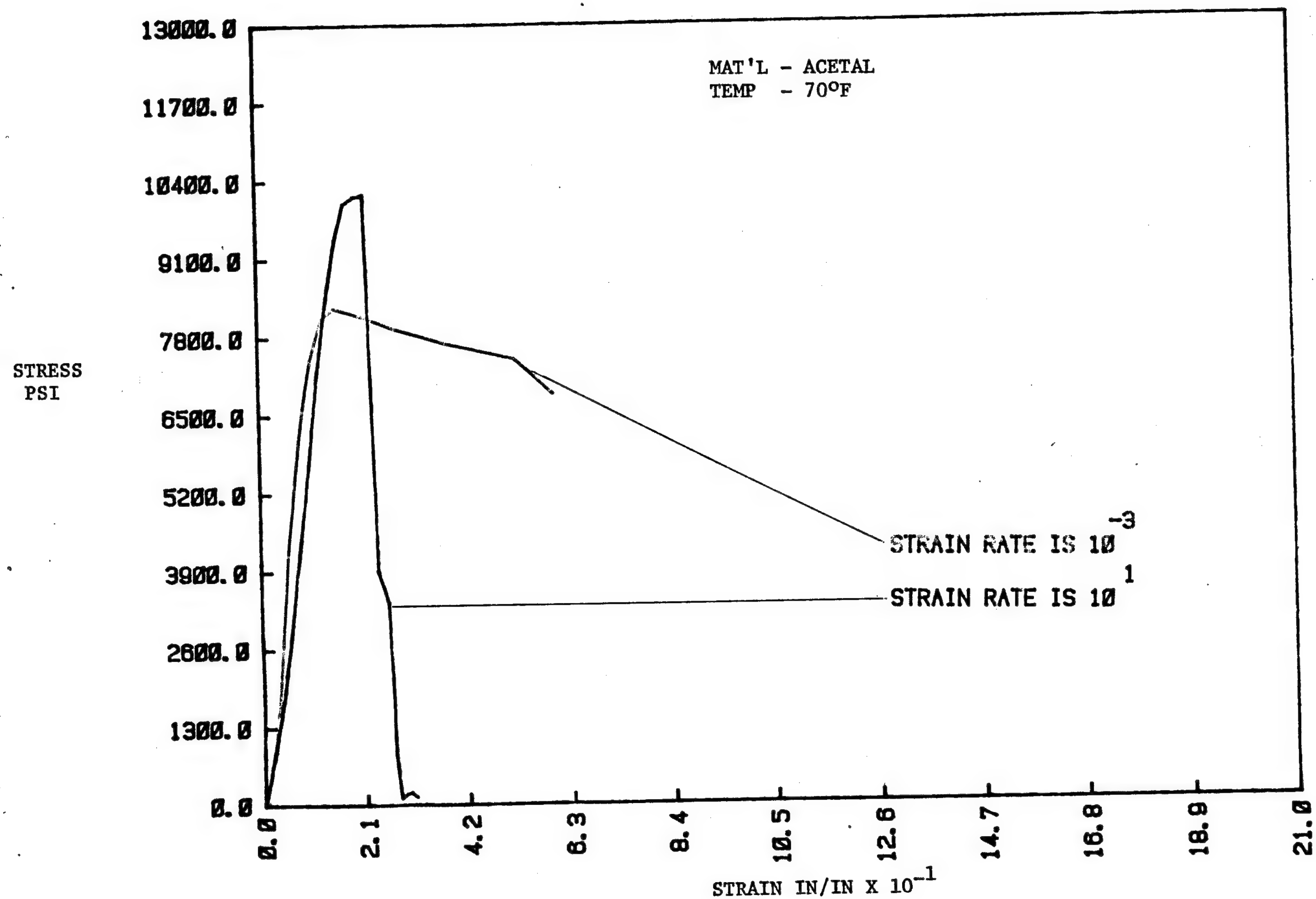

MAT'L - ACETAL
TEMP - 70°F
STRAIN RATE IS 10^-3
STRAIN RATE IS 10^1
STRESS PSI
13000.0
11700.0
10400.0
9100.0
7800.0
6500.0
5200.0
3900.0
2600.0
1300.0
0.0
0.0
2.1
4.2
6.3
8.4
10.5
12.6
14.7
16.8
18.9
21.0
STRAIN IN/IN X 10^-1

FIGURE 7

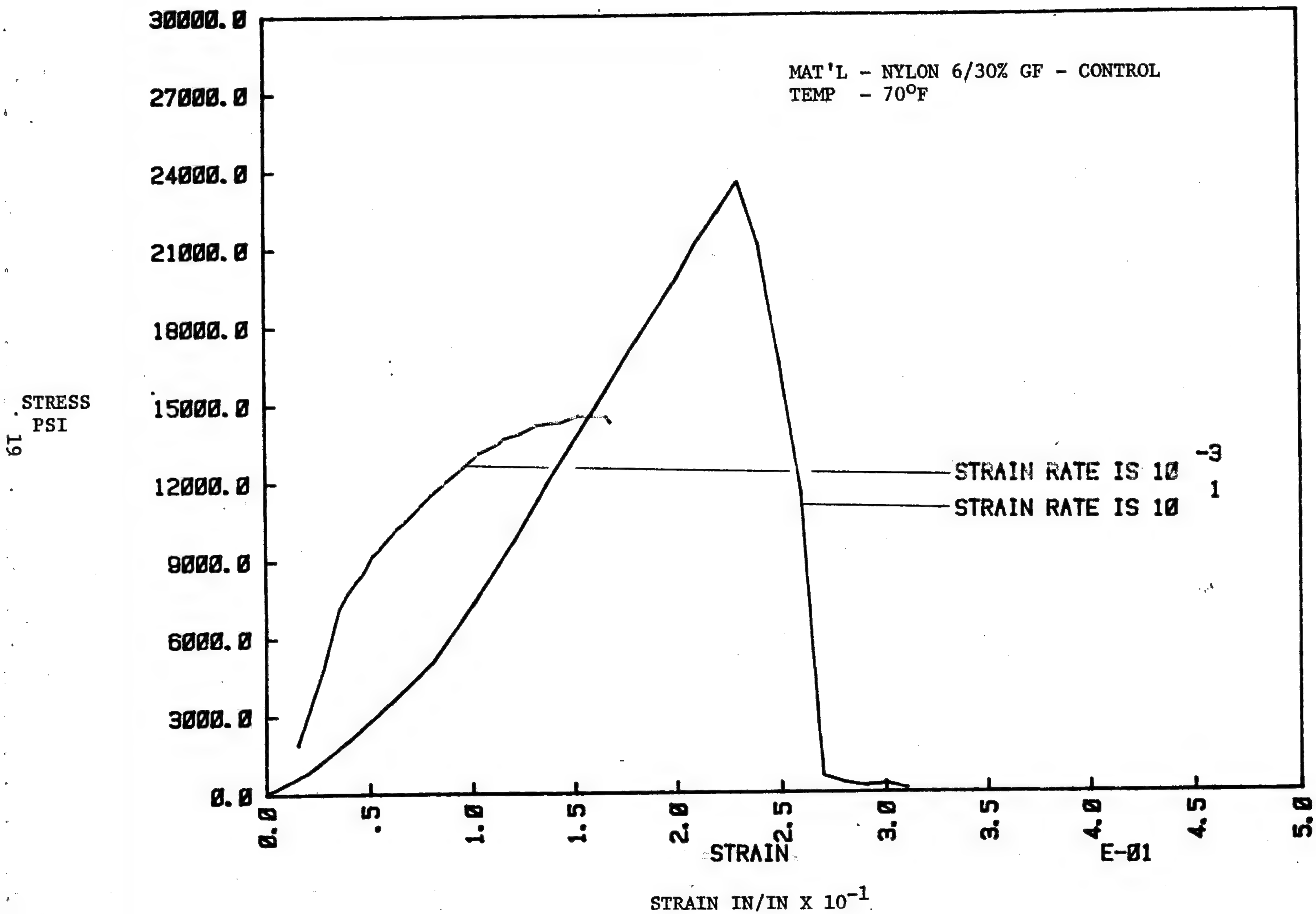
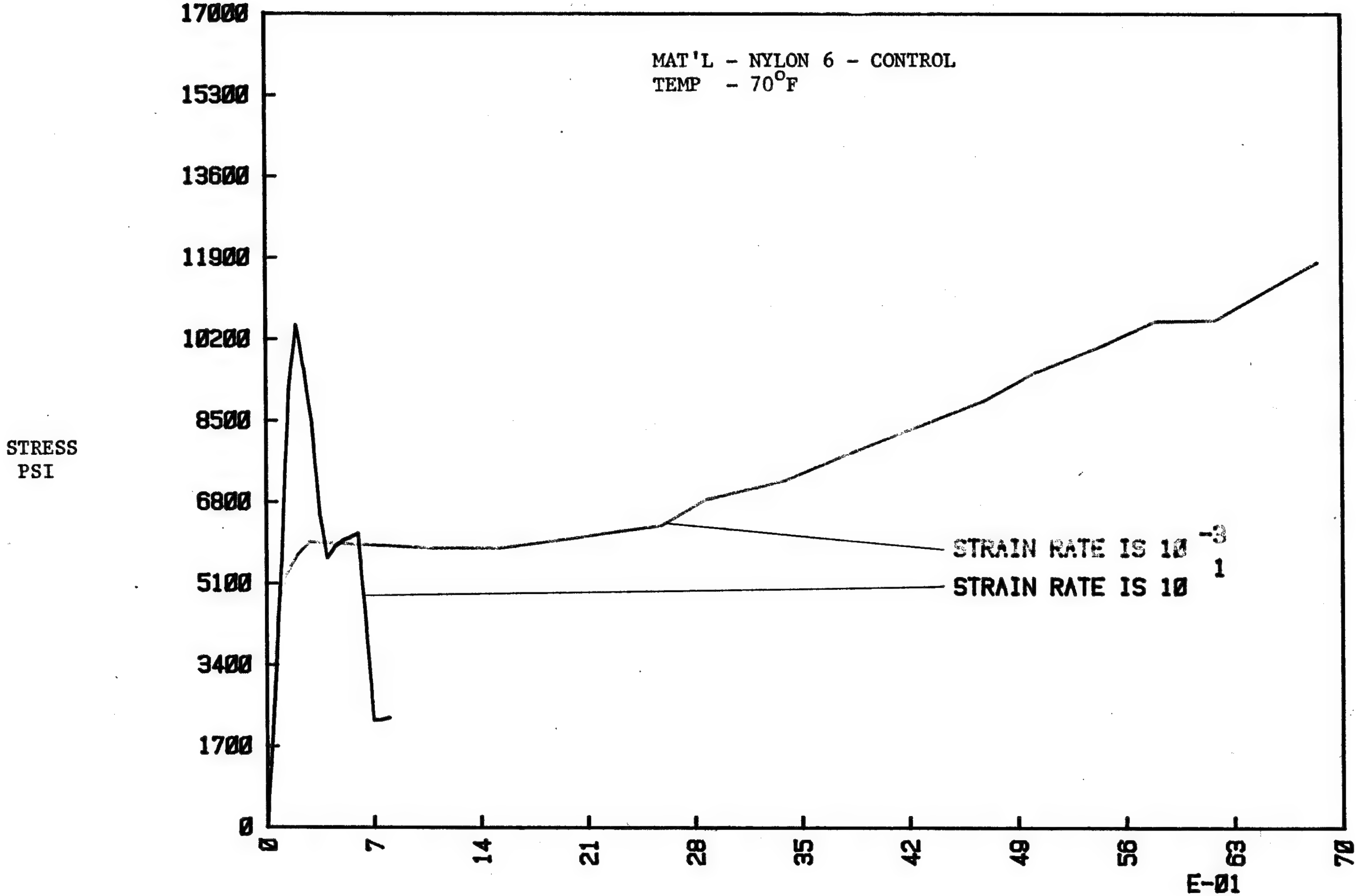
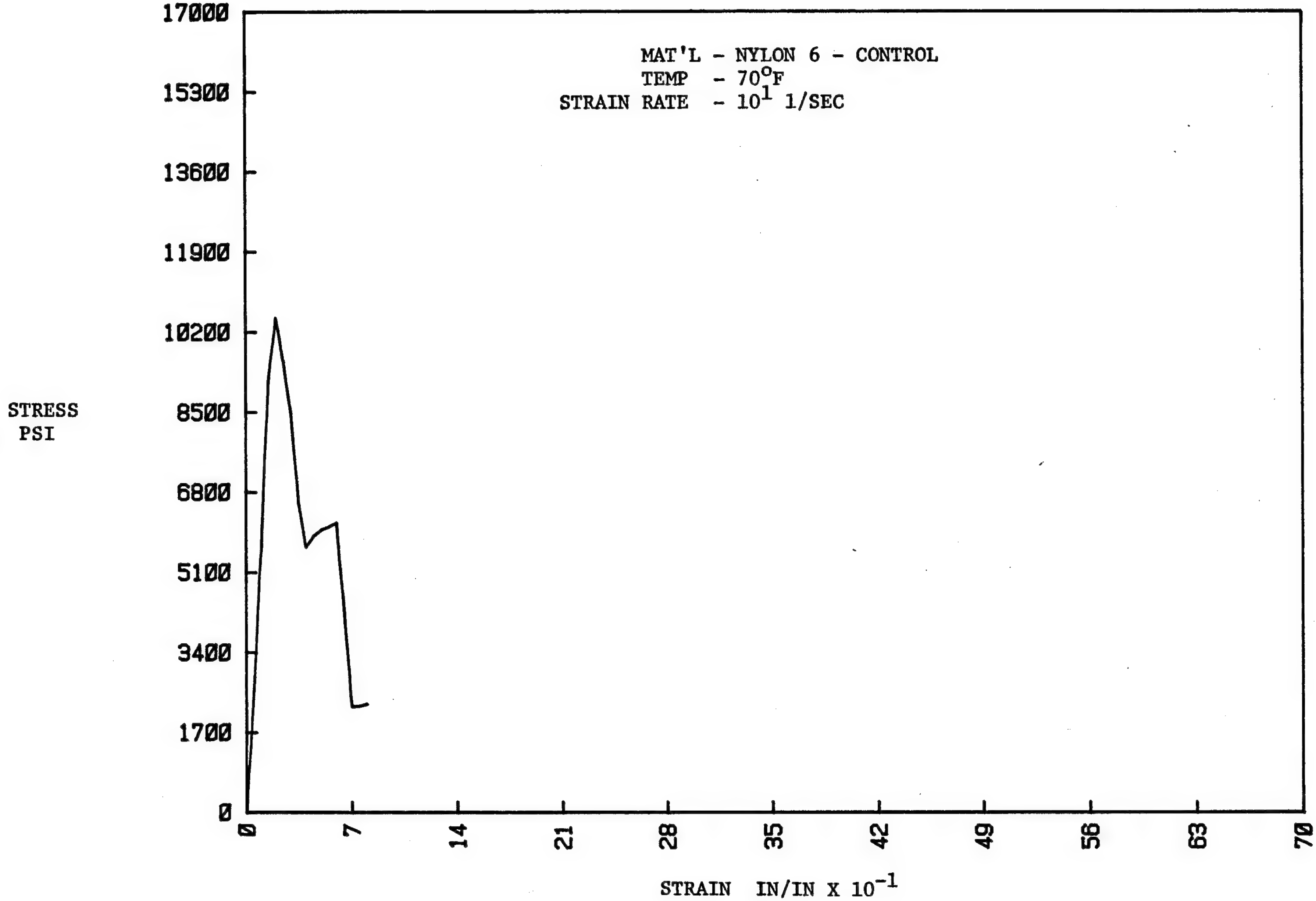

MAT'L - NYLON 6/30% GF - CONTROL
TEMP - 70°F
STRAIN RATE IS 10 -3
STRAIN RATE IS 10 1
STRESS PSI
30000.0
27000.0
24000.0
21000.0
18000.0
15000.0
12000.0
9000.0
6000.0
3000.0
0.0
0.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
STRAIN
E-01
STRAIN IN/IN X 10^-1

FIGURE 8



MAT'L - NYLON 6 - CONTROL
TEMP - 70°F
STRESS PSI
17000
15300
13600
11900
10200
8500
6800
5100
3400
1700
0
7
14
21
28
35
42
49
56
63
70
E-01
STRAIN RATE IS 10 -3
STRAIN RATE IS 10 1
STRAIN (IN/IN X 10-1

FIGURE 9



MAT'L - NYLON 6 - CONTROL
TEMP - 70°F
STRAIN RATE - 10^1 1/SEC
STRESS PSI
17000
15300
13600
11900
10200
8500
6800
5100
3400
1700
0
0
7
14
21
28
35
42
49
56
63
70
STRAIN IN/IN X 10^-1

FIGURE 10

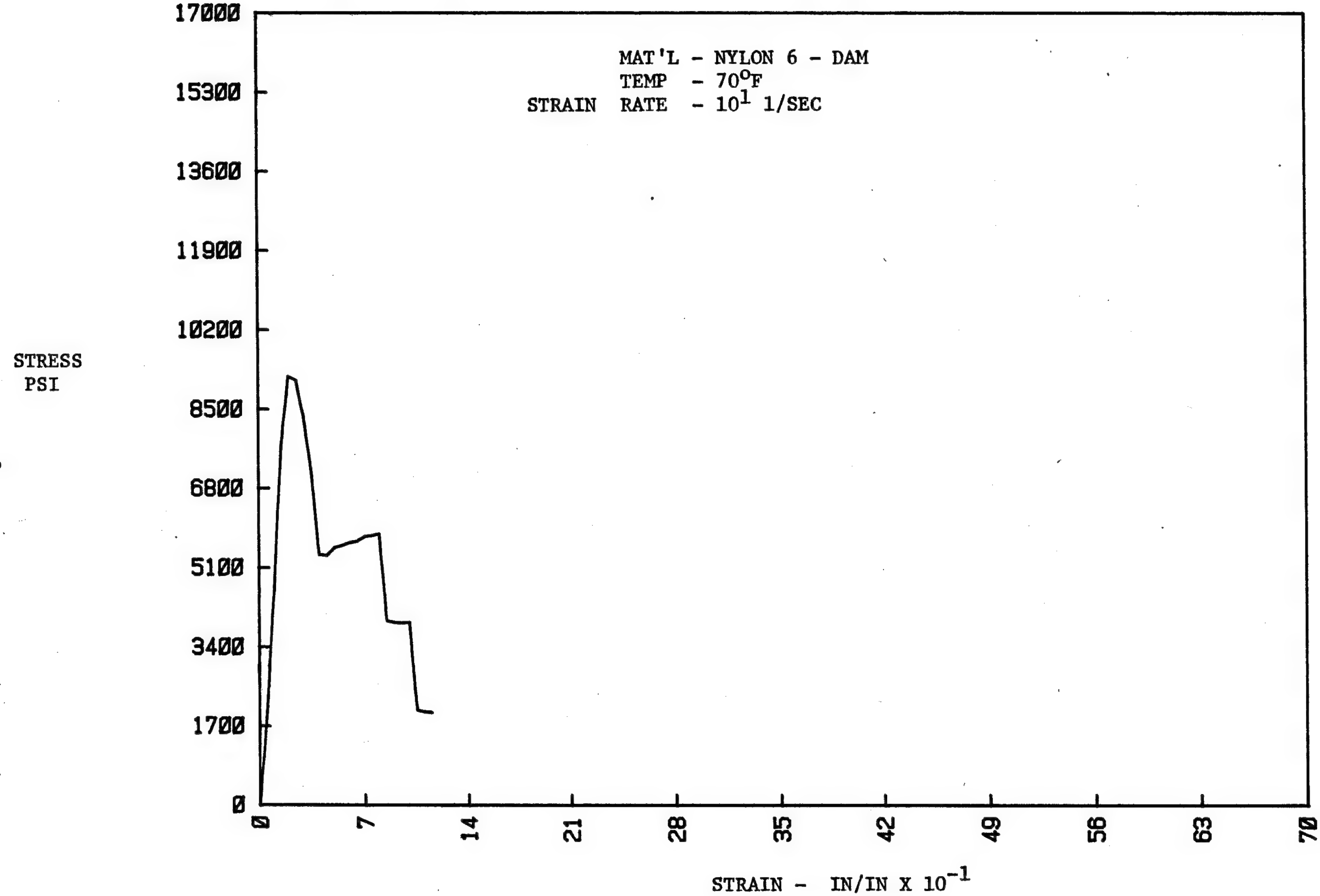

MAT'L - NYLON 6 - DAM
TEMP - 70°F
STRAIN RATE - 10¹ 1/SEC
STRESS PSI
17000
15300
13600
11900
10200
8500
6800
5100
3400
1700
0
0
7
14
21
28
35
42
49
56
63
70
STRAIN - IN/IN X 10⁻¹

FIGURE 11

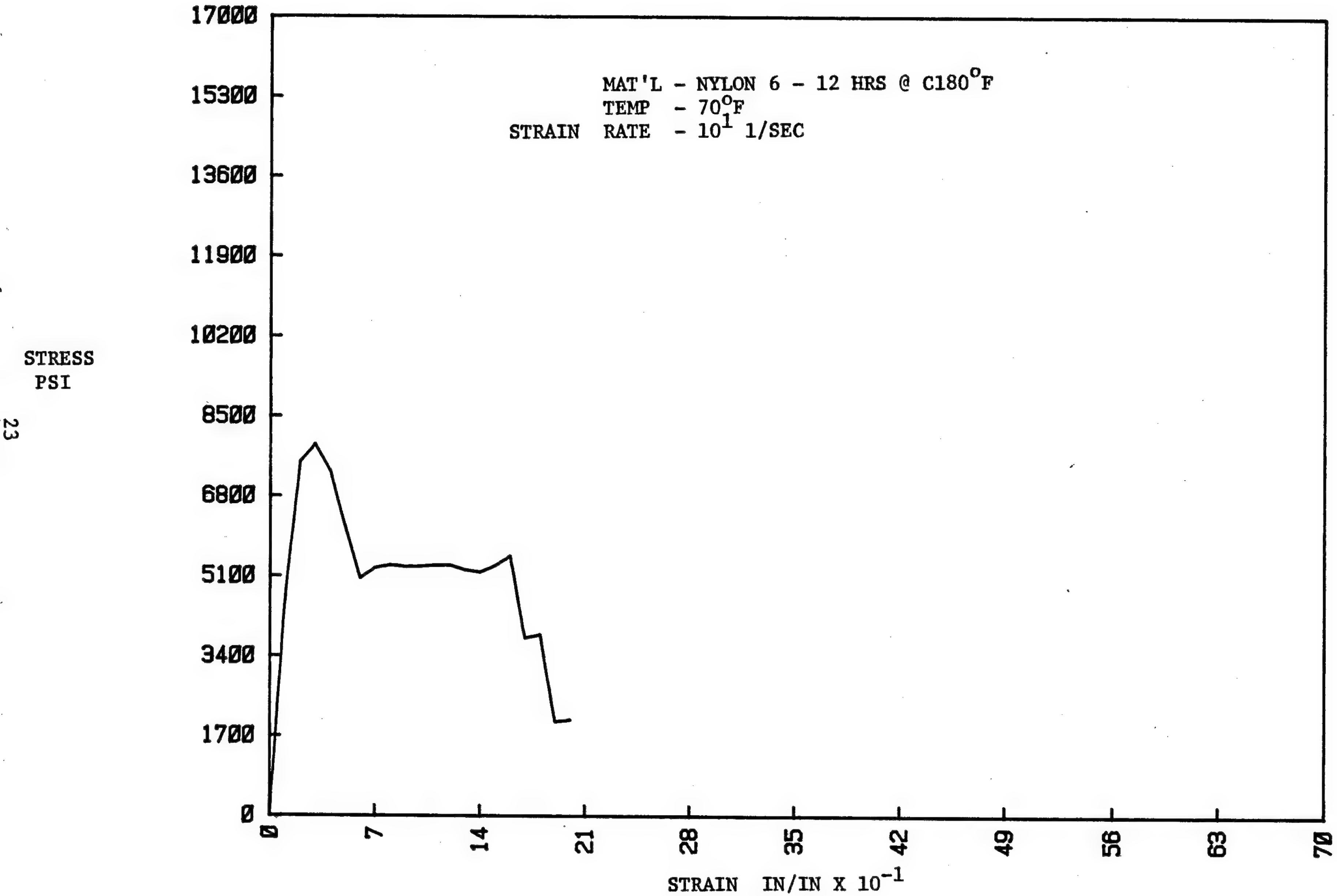

MAT'L - NYLON 6 - 12 HRS @ C180^{o}F
TEMP - 70^{o}F
STRAIN RATE - 10^{1} 1/SEC
STRESS PSI
17000
15300
13600
11900
10200
8500
6800
5100
3400
1700
0
0
7
14
21
28
35
42
49
56
63
70
STRAIN IN/IN X 10^{-1}

FIGURE 12

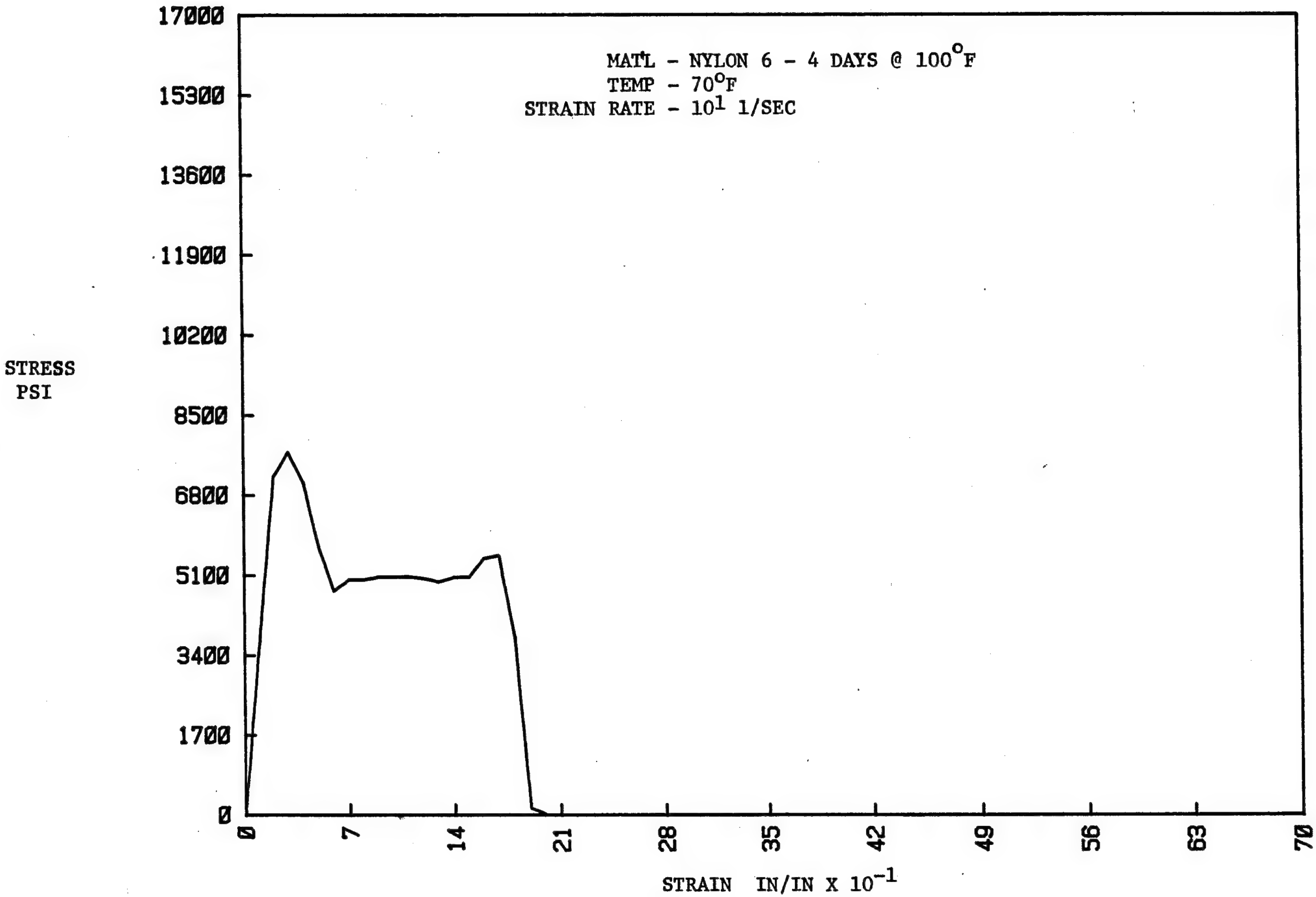

MATL - NYLON 6 - 4 DAYS @ 100°F
TEMP - 70°F
STRAIN RATE - 10¹ 1/SEC
STRESS PSI
17000
15300
13600
11900
10200
8500
6800
5100
3400
1700
0
0
7
14
21
28
35
42
49
56
63
70
STRAIN IN/IN X 10⁻¹

FIGURE 13

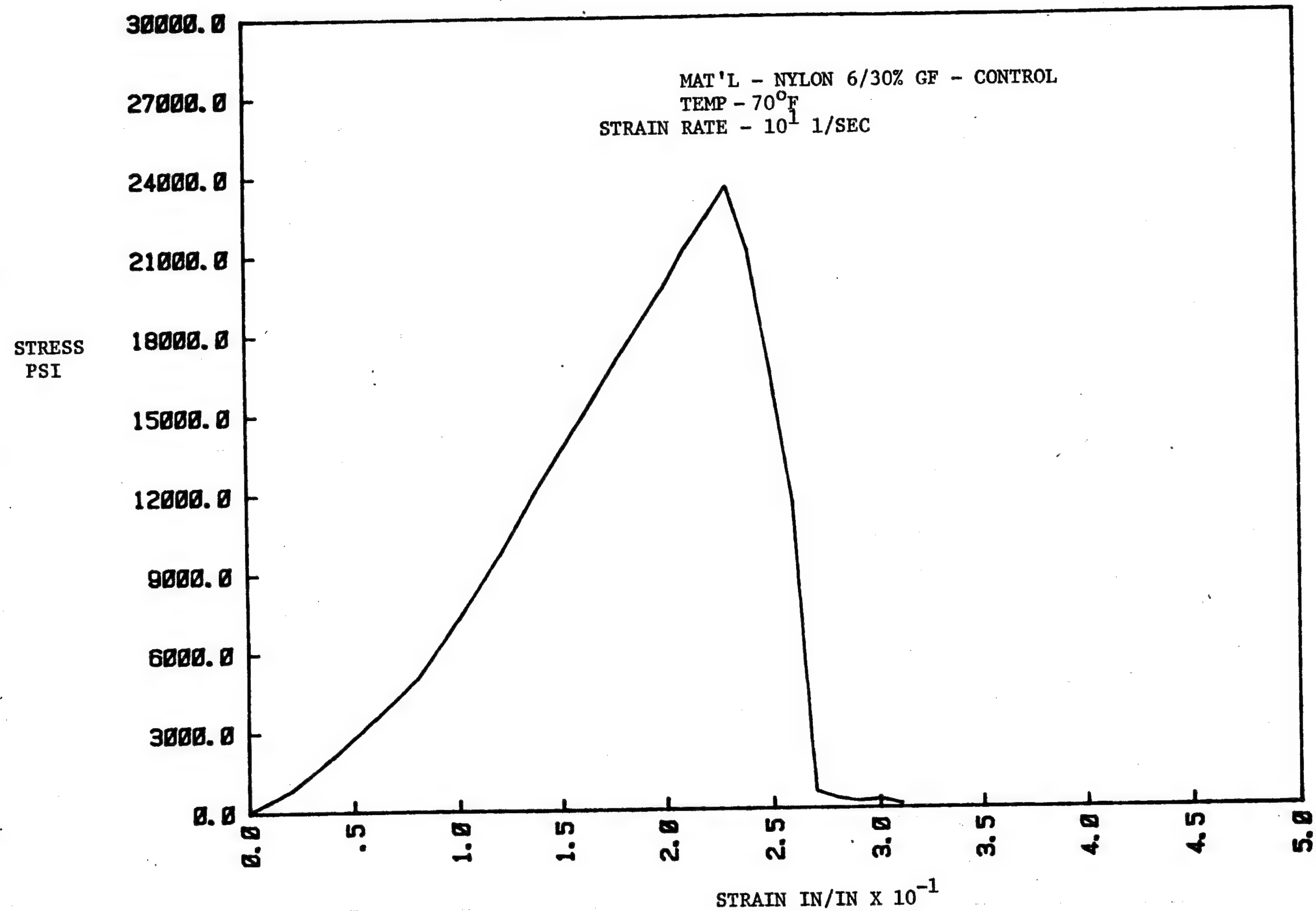

MAT'L - NYLON 6/30% GF - CONTROL
TEMP - 70°F
STRAIN RATE - 10 1 1/SEC
STRESS PSI
30000.0
27000.0
24000.0
21000.0
18000.0
15000.0
12000.0
9000.0
6000.0
3000.0
0.0
0.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
STRAIN IN/IN X 10 -1

FIGURE 14

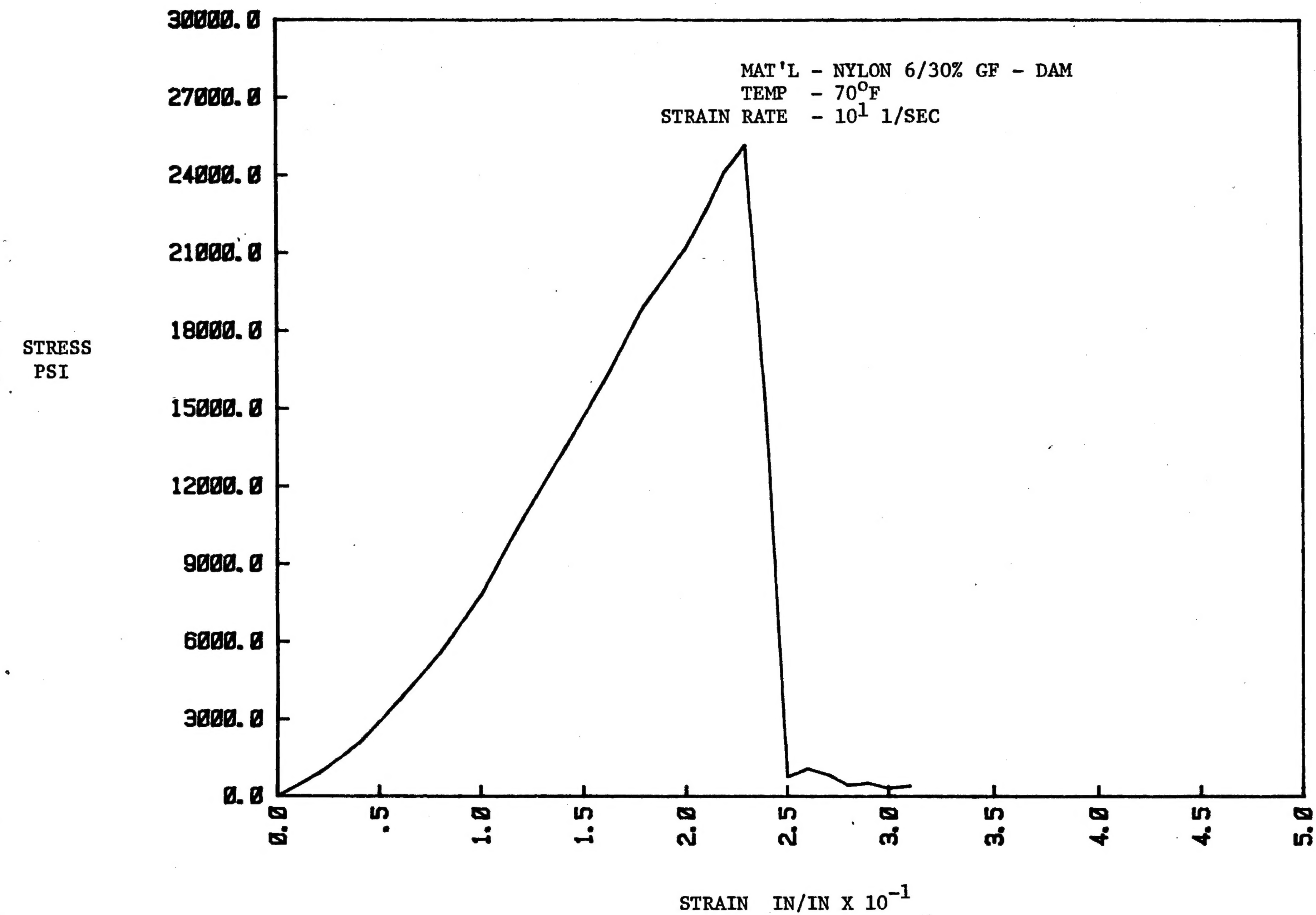

MAT'L - NYLON 6/30% GF - DAM
TEMP - 70°F
STRAIN RATE - 10¹ 1/SEC
STRESS
PSI
30000.0
27000.0
24000.0
21000.0
18000.0
15000.0
12000.0
9000.0
6000.0
3000.0
0.0
0.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
STRAIN IN/IN X 10⁻¹

FIGURE 15

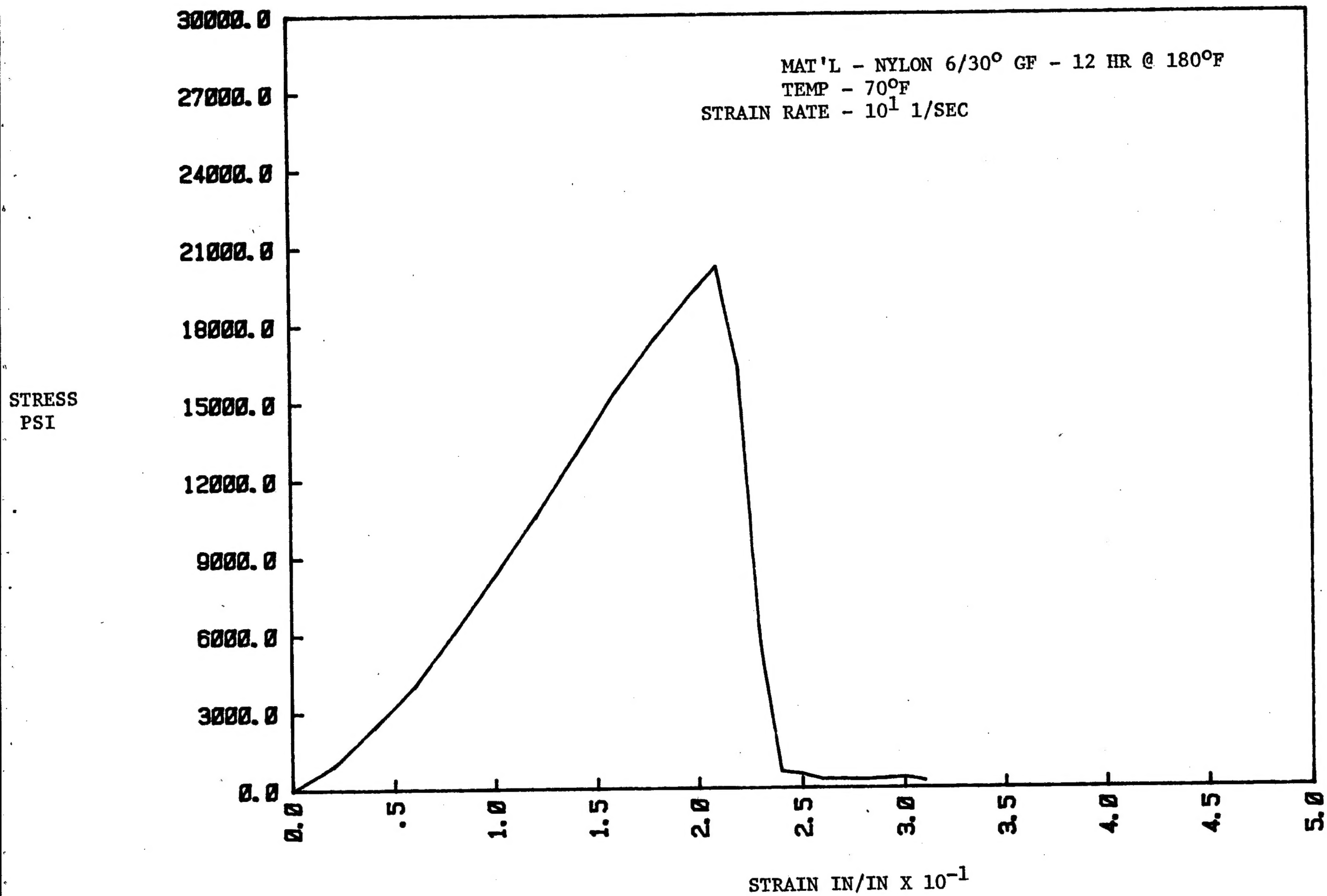
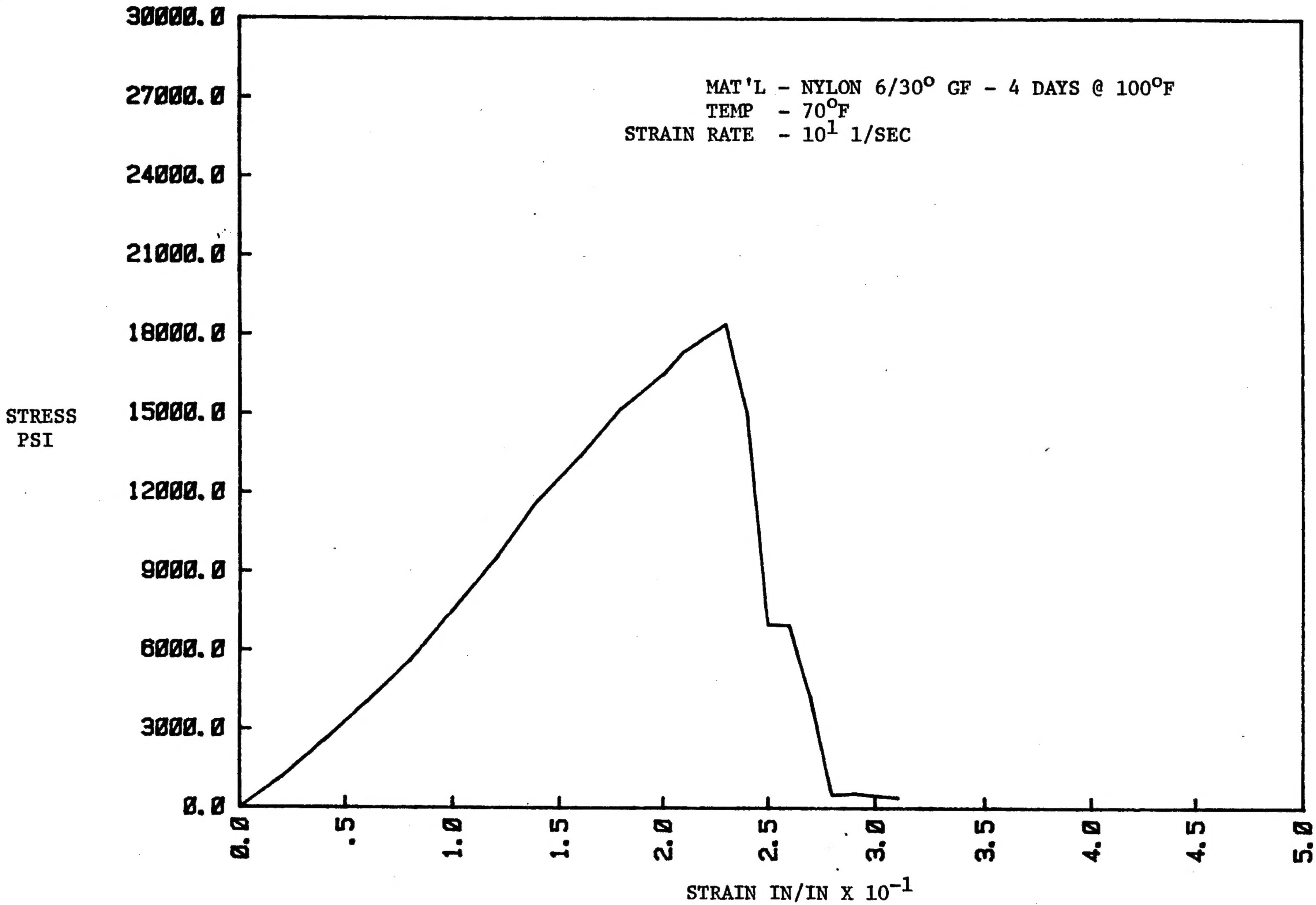
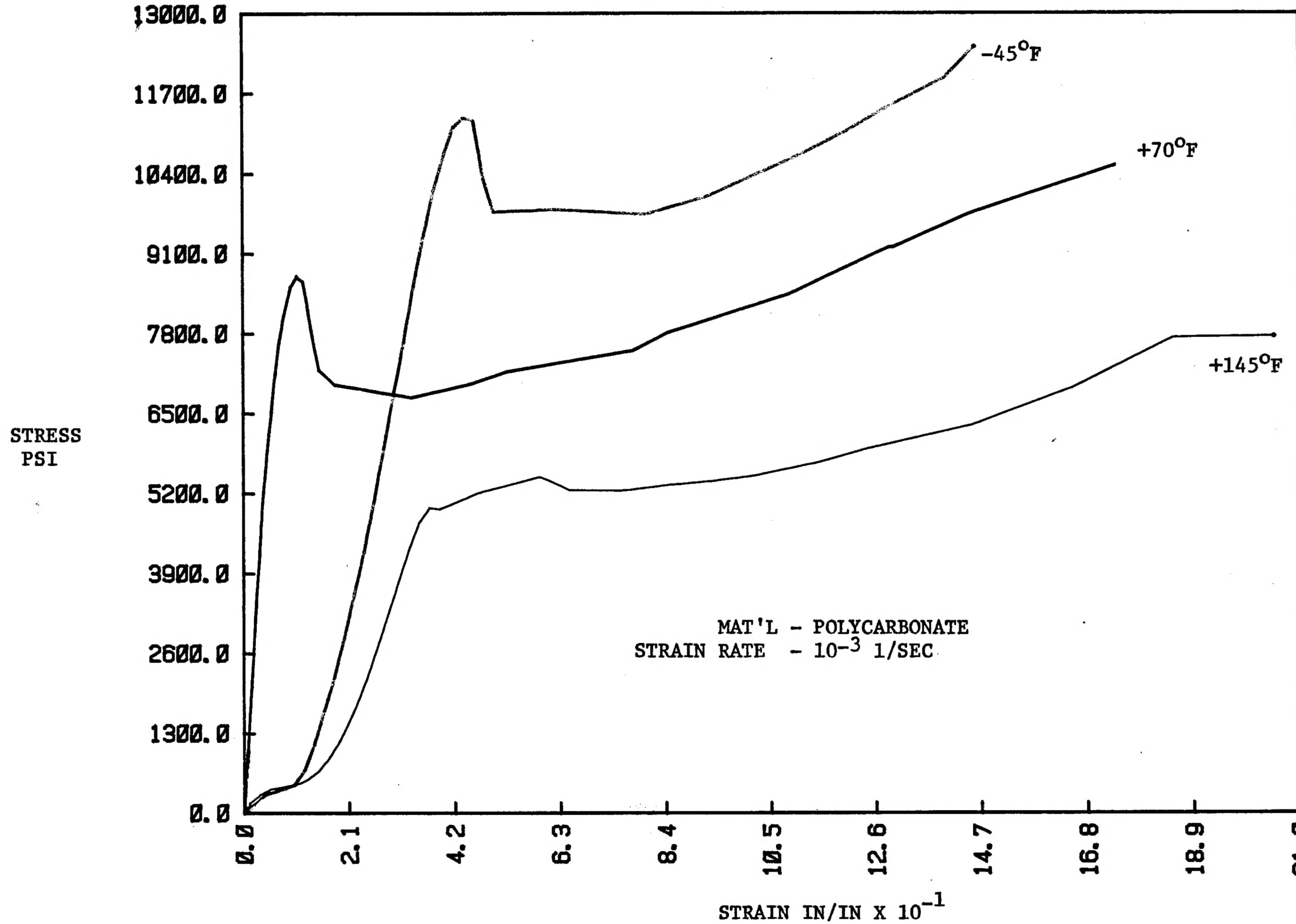

MAT'L - NYLON 6/30° GF - 12 HR @ 180°F
TEMP - 70°F
STRAIN RATE - 10¹ 1/SEC
STRESS
PSI
30000.0
27000.0
24000.0
21000.0
18000.0
15000.0
12000.0
9000.0
6000.0
3000.0
0.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
STRAIN IN/IN X 10⁻¹

FIGURE 16



MAT'L - NYLON 6/30° GF - 4 DAYS @ 100°F
TEMP - 70°F
STRAIN RATE - 10¹ 1/SEC
STRESS PSI
30000.0
27000.0
24000.0
21000.0
18000.0
15000.0
12000.0
9000.0
6000.0
3000.0
0.0
0.0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
STRAIN IN/IN X 10⁻¹

FIGURE 17



STRESS
PSI
13000.0
11700.0
10400.0
9100.0
7800.0
6500.0
5200.0
3900.0
2600.0
1300.0
0.0
-45°F
+70°F
+145°F
MAT'L - POLYCARBONATE
STRAIN RATE - 10-3 1/SEC
0.0
2.1
4.2
6.3
8.4
10.5
12.6
14.7
16.8
18.9
21.0
STRAIN IN/IN X 10-1

FIGURE 18